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TOMOYA SUGITA, *et al.*

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Sir:

Further to the Amendment filed on April 29, 2008, applicants herewith submit a verified English language translation of applicants' Japanese patent application 2003-411441, whose December 10, 2003 filing date antedates the July 1, 1004 filing date of Fischer '009, thereby eliminating Fischer '009 as a de jure prior art reference against the instant application.

Respectfully submitted,

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Declaration

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Osaka, this 30th day of April , 2008

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[Attached Documents]

[Name of Document]	Claim	1
[Name of Document]	Specification	1
[Name of Document]	Drawing	1
[Name of Document]	Abstract	1
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[Name of the Document] Claims

[Claim 1] A laser light source comprising plural semiconductor lasers and a waveguide, wherein the semiconductor lasers are disposed in the waveguide or in a position adjacent to the waveguide, and emitted lights from the semiconductor lasers are inputted to the waveguide from one end surface or a center of the waveguide, and outputted from an end surface of the waveguide different from the one end surface thereof.

[Claim 2] A laser light source as defined in Claim 1 wherein the plural semiconductor lasers are arranged in a direction where the spread angles of the emitted lights from the respective semiconductor lasers are relatively small.

[Claim 3] A laser light source as defined in Claim 1 or 2 wherein a length L from the light emission end surface of the waveguide to the nearest light incident end surface satisfies

$$L \geqq W/\tan(\sin^{-1}(\sin(\theta/2)/n))$$

wherein W is the width of the waveguide, n is the refractive index in the waveguide, and θ is the minimum beam spread angle of the semiconductor lasers.

[Claim 4] A laser light source as defined in any of Claims 1 to 3 wherein the positions of the semiconductor lasers are respectively shifted in the light emission direction with respect to the positions of the other semiconductor lasers.

[Claim 5] A laser light source as defined in Claim 4 wherein the cross-section area of the waveguide varies stepwise

in the light emission direction, and the emitted lights from the semiconductor lasers are incident on the waveguide from the stepwise-processed step-difference portions of the waveguide.

[Claim 6] A laser light source as defined in any of Claims 1 to 5 wherein the oscillation wavelengths of at least two semiconductor lasers are different from each other, and an oscillation wavelength difference A (A: actual number) of the semiconductor lasers whose oscillation wavelengths are most distant from each other is $A \geqq 1$nm.

[Claim 7] A laser light source as defined in Claim 6 wherein the oscillation wavelengths of the semiconductor lasers are different from each other within a range of the oscillation wavelength difference Anm, and an oscillation wavelength interval between arbitrary adjacent semiconductor lasers is (A/2)nm or less.

[Claim 8] A laser light source as defined in Claim 6 or 7 wherein the oscillation wavelength difference A is $A \leqq 30$nm.

[Claim 9] A laser light source as defined in any of Claims 1 to 8 wherein the output light intensities of the respective semiconductor lasers are approximately uniform.

[Claim 10] A laser light source as defined in any of Claims 1 to 9 wherein the semiconductor lasers constitute a multistripe laser array comprising multistripe lasers.

[Claim 11] A laser light source as defined in any of Claims 1 to 9 wherein the semiconductor lasers constitute a

multistack laser array comprising multistack lasers.

[Claim 12] A laser light source as defined in any of Claims 1 to 11 wherein the semiconductor lasers constitute a laser array obtained by linearly arranging plural semiconductor lasers.

[Claim 13] A laser light source as defined in any of Claims 1 to 12 wherein the waveguide is a cell having a hollow structure, and a liquid is sealed in the hollow part.

[Claim 14] A laser light source as defined in Claim 13 further including, in addition to the above-described construction, a cooling mechanism which is connected to the waveguide and circulates the liquid in the waveguide, thereby performing cooling of the laser array.

[Claim 15] A two-dimensional image formation device having a lighting optical system which includes a laser light source as defined in any of Claims 1 to 14 and a spatial light modulation means, and applies the light from the laser light source to the spatial light modulation means.

[Claim 16] A two-dimensional formation device as defined in Claim 15 further including a projection optical system in addition to the above-described construction, wherein output light from the spatial light modulation means is projected by the projection optical system.

[Name of the Document] Specification

[Title of the Invention] Laser Light Source and Two-dimensional Image Forming Device

[Technical Field]

[0001]

The present invention relates to a laser light source having a high output power and a uniform emission light intensity distribution. Further, the invention relates to a two-dimensional image forming device using the laser light source.

[Background Art]

[0002]

A high-output light source has a wide range of application such as a semiconductor exposure device, an image display device, a lighting device, and the like, and research and development thereof are proceeding. Particularly, application of a light source using a high-power laser to formation of a clear image having high chromatic purity by a laser display using a high-output laser of three primary colors, i.e., R, G, and B, has been considered, utilizing monochromaticity of the high-output laser light source. Further, micro-patterning using laser processing is being put to practical use. Further, realization of a small-size and high-power laser light source is expected as a light source for lighting purpose, having reduced power consumption and long life.

[Patent Document 1] Japanese Published Patent Application No.

Hei.07-306304

[Patent Document 2] Japanese Patent Publication No.3410813

[Patent Document 3] Japanese Published Patent Application No. 2002-40327

[Patent Document 4] Japanese Published Patent Application No. 2003-57514

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0003]

However, these applications using the high-power laser light source have great demands for uniform intensity distribution. So, in the conventional methods, a Gaussian light intensity distribution emitted from the laser is formed using a device or an optical system for homogenizing the light quantity, which is called a homogenizer, as described in Patent Document 1 or Patent Document 2, or using an optical device which is called an integrator as described in Patent Document 3 or Patent Document 4. However, since it is necessary to appropriately increase the cross section area of the light incident on the device or the optical system, the optical system including the laser light source is complicated and significantly increased in size. Further, a rod integrator as described in Patent Document 4 has a problem that, due to its function, the length of the integrator itself in the light propagating direction. Further, especially when using a high-coherent laser light source, the light emitted

from the light quantity homogenizing device described in Patent Document 1 to Patent Document 4 has a fine interference pattern that is peculiar to laser light, which is called "speckle noise", and therefore, it is necessary to provide a speckle noise removal means when the emitted light is used in an image display device or a lighting device.

[Measures to solve the Problems]

[0004]

In order to solve the above-described problems, according to the present invention, there is provided a laser light source comprising plural semiconductor lasers and a waveguide, wherein the semiconductor lasers are disposed in the waveguide or in a position adjacent to the waveguide, and emitted lights from the semiconductor lasers are inputted to the waveguide from one end surface or a center of the waveguide, and outputted from an end surface of the waveguide different from the one end surface thereof. Further, there are provided a lighting optical system including the laser light source and a spatial light modulation means, and a two-dimensional image formation device.

[Effects of the Invention]

[0005]

In the present invention, it is possible to realize a small-size and high-power laser light source having a uniform emission light intensity distribution. Further, it is possible to reduce speckle noise which occurs in a highly coherent laser light

source by distributing the output wavelengths of the semiconductor lasers constituting the laser light source at appropriate intervals within a specific wavelength range. Furthermore, it is possible to similarly reduce the speckle noise by adopting a hollow cell as the waveguide and sealing an appropriate liquid or gas in the cell. Moreover, the high-power lasers and the waveguide can be efficiently cooled by circulating the liquid in the cell using a cooling unit connected to the hollow cell, thereby achieving stability and long life of the light source.

[Best Mode to Execute the Invention]

[0006]

Hereinafter, embodiments of the present invention will be described with reference to the drawings.

[0007]

(Embodiment 1)

Research and development of laser light sources are remarkable, and small-size high-power laser light sources represented by semiconductor lasers have advanced to practical use. Taking a semiconductor laser as an example, there is a multimode semiconductor laser that achieves an output of several W class, although its output wavelength is limited. Conventionally, laser light sources have mainly been applied to those utilizing focusing property of laser light and height of coherent light, such as measurement, optical communication, and

optical disc. On the other hand, with reduction in size and increase in output power of laser light sources, exploitation of applications as well as development of devices have been intensified, and applications of the laser light sources to image display devices, lighting devices, semiconductor exposure devices, and the like have been expected. In these applications, however, in addition to utilization of monochromatic characteristics and high-output characteristics of laser light are utilized, there has been a demand for realization of uniform cross-section light intensity distribution. As a method that satisfies this demand, for example, emitted light from a laser light source is collimated to be expanded to a certain measure of size, and then it is formed into a beam through an optical element or an optical system called a light integrator or a homogenizer which is obtained by combining a lens and a filter, thereby obtaining an approximately uniform light intensity distribution. At this time, since the outer circumference of the beam should be cut off, the laser output light cannot be sufficiently utilized. Further, since the optical system used for the above-mentioned method is complicated and increased in size, it is difficult to realize a small-size device. So, we propose a method for achieving a small-size, high-power, uniform-intensity laser light source in the present invention, and verify the practicality thereof.

[0008]

Initially, a description will be given of the reason why

high-power output and uniformization of cross-section intensity distribution of emitted light can be realized using semiconductor lasers and a waveguide. In figure 1, 1 denotes semiconductor lasers, 2 denotes a laser array obtained by linearly arranging the semiconductor lasers 1, 3 denotes a waveguide comprising a glass material, and 4 denotes a emitted light from the waveguide 3. On a peripheral surface of the waveguide 3 excluding a surface on which laser lights from the semiconductor lasers 1 are applied and a laser light emission end surface, a reflection film such as a metal film comprising an Al material is formed to efficiently perform confinement of light into the waveguide 3. Further, X, Y, Z in the figure are expediential directions, and X is a vertical direction of the waveguide, Y is a direction in which the semiconductor lasers 1 are arranged in an array or a width direction of the waveguide, and Z is a light propagating direction in the waveguide. Hereinafter, the function of the above-mentioned construction will be described. The laser lights emitted from the semiconductor lasers 1 constituting the laser array 2 are combined and inputted to the waveguide 3. The combined incident laser lights propagate in the waveguide while repeating total reflection and are outputted as an emission light 4 from the waveguide 3. Although the laser lights that enter the waveguide 3 have the respective Gaussian cross-section light intensity distributions when being emitted from the respective semiconductor lasers 1, the plural laser lights emitted from the

respective semiconductor lasers 1 are mixed while propagating in the waveguide with repeating multiple reflection, the cross-section light intensity distributions are made uniform, whereby the light intensity distribution viewed at the cross section of the waveguide 3 (the plane perpendicular to the light propagating direction) is gradually made uniform in the plane with distance from the light incident surface in the light propagating direction. Accordingly, a uniform cross-section light intensity can be obtained until reaching the emission surface by setting the length of the waveguide 3 in the light propagating direction to an appropriate value. By the way, general semiconductor lasers (AlGaAs, AlGaInP, and GaN semiconductor lasers) have different aspect ratios and different spread angles of emission lights, and have relatively large spread angles in the vertical direction (X direction in figure 1). Accordingly, when using a waveguide having a cross-section aspect ratio of approximately 1, the waveguide length required for making the cross-section intensity distribution uniform in the direction where the spread angle is relatively large must be short while the waveguide length in the direction where the spread angle is relatively smaller must be long. So, we have discovered that, when the plural semiconductor lasers are arranged in the direction where the spread angle is relatively small (Y direction) to constitute the laser array 2 as shown in figure 1, the laser beams oscillated from the respective semiconductor lasers can easily be

mixed within the plane perpendicular to the X direction, whereby the cross-section light intensity distribution of the emission light 4 can be made uniform within a very short distance. Figure 2 is a schematic diagram illustrating how the intensity distributions of the lights outputted from the laser array are mixed with propagation of the lights (corresponding to a top plan view when figure 1 is viewed from the X direction). In figure 2, 5 denotes semiconductor lasers, 6 denotes a laser array obtained by linearly arranging the semiconductor lasers 5, and 7 denotes a waveguide. Further, in figure 2, Z denotes a light propagating direction, and A-A', B-B', and C-C' denote light intensity distributions at arbitrary cross sections of the waveguide 7. In figure 2, the side surfaces of the waveguide 7 are not shown for simplification (it is assumed that the side surfaces are positioned away). As is easily seen from figure 2, the laser lights are mixed while propagating in the waveguide, whereby the light intensity distributions are made uniform. Although reflections of the laser lights at the side surfaces of the waveguide 7 are ignored, since the laser lights reaching the Y-direction side surfaces of the waveguide are total-reflected at the side surfaces when the width of the waveguide 7 in the Y direction is made approximately equal to the width of the laser array 6, the light intensity distributions are folded at the side surfaces and thereby mixing of the light intensity distributions is further complicated to be promoted. Further, by using laser

arrays 2 disposed upper and lower two positions in the waveguide 3 as shown in figure 1, mixing of lights in the X direction can also be performed easily, and thereby the length of the waveguide 3 can be further reduced as compared with the case where the laser array 2 is disposed at only the upper side of the waveguide 3. As described above, one of the advantageous points of the present invention resides in that the total light output intensity as a light source can be easily increased by using the laser array comprising the plural high-power semiconductor lasers and the waveguide. The laser array 2 of this first embodiment is fabricated by a semiconductor process, and thereby the laser light emission positions as well as the intervals between the adjacent semiconductor lasers 1 can be easily controlled. Further, the waveguide 3 comprises a quartz glass, and it is processed into a shape on which the laser array 2 can be disposed as shown in figure 1 by using a high-precision machining process and a grinding process. The above-mentioned processing can also be carried out with high precision by using dry etching. The laser array 2 is bonded to the processed part of the waveguide 3 by using such as a resin or a solder, thereby realizing a high-power laser light source in which the cross-section light intensity at the emission end of the waveguide 3 is uniformized. Further, the emission facet aspect and the emission light intensity of the waveguide 3 can be arbitrarily designed by controlling the intervals and the number of the semiconductor

lasers 1 constituting the laser array 2.

[0009]

While in this first embodiment the high-reflection film is formed on the peripheral surface of the waveguide 3 other than the laser light input/output end facets, if the waveguide 3 has a configuration which satisfies the condition of total reflection with respect to the propagating lights, the low-loss light propagation can be achieved even when the high-reflection film is not provided, and the same effects as mentioned above can be obtained.

[0010]

While in this first embodiment the laser array constituted by linearly arranging the semiconductor lasers 1 is described as an example, a similar high-power light source having a uniform output light intensity distribution can be realized by arranging plural semiconductor lasers at equal intervals.

[0011]

As another example of the present invention, a higher-power laser light source with a uniformized light intensity distribution can be realized by arranging laser arrays in a stack. Especially in a high-power semiconductor laser and a laser array, heat radiation during laser light emission is a serious problem in view of output stability and lifetime. So, we have considered to efficiently remove the heats generation from the semiconductor lasers by using a construction in which the laser emission facets

are shifted in the light emission direction so that the upper and lower surfaces of the stacked laser arrays are not closely disposed as shown in figure 3. In figure 3, 8 denotes semiconductor lasers, 9 denotes laser arrays each obtained by linearly arranging the semiconductor lasers 8, 10 denotes a waveguide, and 11 denotes laser light emitted from an emission end surface of the waveguide 10. In this construction, the fundamental function of the waveguide 10 (uniformization of the cross-section intensity of the emitted light) is identical to that of the case shown in figure 1. An advantage of this construction resides in the heat radiation mechanism obtained when the laser arrays 9 comprising the high-power semiconductor lasers 8 are disposed as closely as possible to constitute a high-power light source. As for heat radiation of the semiconductor lasers, it is generally considered that efficient heat radiation can be performed when the semiconductor lasers 1 are fixed to a substrate comprising a material having a high heat conductivity such as a silicon submount so that heat radiation is performed in a pane parallel to the active layers of the semiconductor lasers 1. Accordingly, in order to perform efficient heat radiation also in the laser arrays 9, heat radiation should be performed at the surfaces of the laser arrays 9 in the X direction. At this time, however, if the laser light emission surfaces of the laser arrays 9 which are disposed in a stack are within approximately the same plane, heat radiation is

deteriorated, and efficient elimination of generated heat cannot be achieved. So, the laser emission facet positions of at least adjacent laser arrays 9 are shifted in the light propagating direction to expose the surfaces of the laser arrays 9 in the X direction, whereby measures for cooling can be easily taken. According to our experiment, the above-mentioned shift amount is taken by the length of the laser array in the Z direction (several 100μm to several mm in a common high-output laser), thereby realizing a most efficient and compact high-power light source.

[0012]

In the constructions of the above-described laser light sources, since the length of the waveguide in the Z direction becomes a major factor in determining the device size, a design for realizing a laser light source as compact as possible is required. An optical path of the semiconductor laser light that propagates in the waveguide is geometric-optically illustrated in figure 4. Figure 4 is a sectional side view of a simplest construction in which a single semiconductor laser and a waveguide are disposed. In figure 4, 12 denotes a semiconductor laser, and 13 denotes a waveguide comprising a transparent material having a refraction index n. Further, $\theta 1$ denotes a spread angle of the laser light in the waveguide 13, and it is expressed by a full angle at half maximum of the light intensity distribution. Further, W denotes the width of the waveguide 13

in the laser light spreading direction, and L denotes the length from the laser light incident surface to the emission surface of the waveguide 13. In figure 4, when the laser light is incident on the waveguide 13, a portion of the light intensity distribution that reaches the side surface of the waveguide 13 is reflected, and thereby the light intensity distribution which is folded and overlapped at the side wall of the waveguide 13 is observed in the area up to the emission end surface of the waveguide 13. This state is schematically shown in figure 5. Figure 5(a) shows the intensity distribution in the case where the laser beam propagates in the free space, figure 5(b) shows the overlapping state of the light intensity distributions which is obtained when the light intensity distribution is reflected at the side wall of the waveguide, and figure 5(c) shows the actually overlapped light intensity distributions. For easy understanding, figures 5(a) to 5(c) show the light intensity distributions at arbitrary cross sections D-D', E-E', and F-F' in the light propagating direction. In figures 5(a) to 5(c), 14 denotes a semiconductor laser, and 15 denotes a waveguide comprising a transparent material having a refractive index n. Further, $\theta 2$ denotes a spread angle of the semiconductor laser 14, and $\theta 3$ denotes a spread angle of the laser light in the waveguide 15 having a refractive index n. As shown in figure 5(a), the emitted light from the semiconductor laser 14, which is propagating in the free space, gradually spreads with the spread

angle $\theta 2$. At this time, if the waveguide as shown in this first embodiment is absent, the spatial spreading of the light intensity is increased but its intensity distribution does not change, and the Gaussian type intensity distribution is maintained. However, when the waveguide 15 that totally reflects the laser light at its side wall is present, the spread angle $\theta 3$ of the laser light that is incident on the waveguide 15 having the refractive index n is expressed by

$$\theta 3 = 2 \times \sin^{-1}((\sin(\theta 2/2))/n)$$

Assuming that the width of the waveguide 15 is W, when the incident light reaches a position where the distance from the incident surface is $W/(2 \times \tan(\sin^{-1}(\sin(\theta 2/2)/n)))$, a portion of the light intensity distribution starts to be reflected at the side wall of the waveguide 15. Thereafter, the reflected light intensity distribution gradually increases, and the light intensity distribution which is obtained by folding and overlapping the light intensity distribution in the case where the side wall of the waveguide 15 is absent, at a position corresponding to the width W of the waveguide 15 is observed in the area up to the emission end surface. At this time, in order to make the substantial cross-section light intensity which is obtained by overlapping the light intensity distribution folded by reflection and the non-reflected light intensity distribution (shown in figure 5(c)) sufficiently uniform, the length of the waveguide 15 should be sufficiently long to increase the number

of total reflections. However, from the aspects of device fabrication and usage, it is desired that the laser light source should be as compact as possible. According to our study, it was discovered that, assuming that the spread angle of the emitted laser light is $\theta 3$, the width of the waveguide 13 in the direction perpendicular to the laser light propagating direction is W, and the length from the laser light incident surface to the emission end surface of the waveguide 13 is L, the light intensity distribution is made uniform so long as at least the following condition is satisfied:

$$L \geqq W/\tan(\sin^{-1}(\sin(\theta 3/2)/n))$$

[0013]

Figure 6(a) shows a sectional side view in the case where the two laser arrays described in this first embodiment are disposed on the upper and lower surfaces of the waveguide, and figure 6(b) shows a sectional side view in the case where the laser arrays are disposed in a stack on the waveguide with the emission positions being shifted in the light propagating direction according to the other example of the first embodiment. While in the above description figure 4 is used for simplification, the conception is identical also in figures 6(a) and 6(b), and a compact and high-power light source having a uniform light intensity distribution can be realized by adopting the waveguide length that satisfies the above-described condition. Further, since the cross-section area of the waveguide varies

stepwise in the light propagating direction as shown in figure 6(b), the incident laser lights from the respective semiconductor lasers are totally reflected at the side surfaces of the waveguide, thereby avoiding loss in light quantity which is caused by that some semiconductor lasers are hidden behind other semiconductor lasers. Accordingly, most of the light quantity of the laser light incident on the waveguide can be efficiently propagated in the waveguide.

[0014]

As means for facilitating the high power output of the light source for uniformizing the light intensity distribution, which has the laser array and the waveguide described in this first embodiment, commonly used multi-stripe lasers or multi-stack lasers may be used with the same effects as mentioned above.

[0015]

As another example of the present invention, a description will be given of a light source which can easily remove speckle noise that is unique to laser light sources, by controlling the oscillation wavelengths of the semiconductor lasers constituting the laser array. The speckle noise is fine uneven noise that is caused by interference of scattering lights from the plural parts on the screen when the laser light is scattered on the screen in the case where image projection is carried out on the screen using a laser light source. In order to remove this speckle noise, there have been adopted a method of vibrating a screen,

and a method of giving temporally and spatially random phases to the laser light by transmitting the laser light through a diffuser. However, the method of vibrating the screen has a problem that the screen cannot be fixed, and the method using the diffuser has a problem that the quantity of light used for image projection is reduced. The laser light source of the present invention achieves a high-power and uniform sectional light intensity using a laser array and a waveguide as described in the first embodiment. In this construction, the above-mentioned problems can be solved by controlling the oscillation wavelengths of the semiconductor lasers constituting the laser array. Hereinafter, the laser oscillation wavelength control and its effect will be described. As described above, the speckle noise occurs when highly coherent laser light is used, and it is caused by interference of scattering lights on the screen. Accordingly, it is possible to reduce the speckle noise by temporally and spatially disordering the phases of the laser lights outputted from the light sources at random to average the speckle patterns observed by the laser lights from the respective light sources. So, we have studied a method for reducing the speckle noise using a laser array constituted by semiconductor lasers having different output wavelengths in the light source using the laser array according to the present invention. Since different speckle patterns are obtained from light sources of different wavelengths, when plural semiconductor lasers having different

wavelengths are used, a speckle pattern to be finally observed on the screen is one obtained by overlapping the speckle patterns from the respective semiconductor lasers. Spatial averaging of the plural speckle patterns can be efficiently performed when the respective speckle patterns are obtained independently from each other (without correlation). The speckle noise which is seen when the screen is observed is caused by interference of reflected laser lights at irregularities on the screen surface. Here, as a simple example, a speckle pattern caused by two semiconductor lasers of different oscillation wavelengths will be considered. In semiconductor lasers having oscillation wavelengths $\lambda 1$ and $\lambda 2$, respectively, when a phase difference of reflected lights at a depression part and a projection part is equivalent to one wavelength or more, speckle patterns due to the laser lights of $\lambda 1$ and $\lambda 2$ which are obtained when the laser lights are applied onto the screen have less correlations with each other. As a very general example, it is assumed that a screen having depressions and projections of $100\mu m$ is irradiated using two semiconductor lasers having different wavelengths of $\lambda 1$ and $\lambda 2$ ($\lambda 2=\lambda 1+\Delta\lambda$). An optical path difference between the light of wavelength $\lambda 1$ that is scattered and reflected at the highest portion on the screen surface (projection) and the light of wavelength $\lambda 2$ that is scattered and reflected at the deepest portion on the screen surface (depression) should be $(200/\lambda 2)\times\Delta\lambda \geqq \lambda 1$. Assuming that $\lambda 2$=470nm (visible light of blue) because

$\lambda 2=\lambda 1+\Delta\lambda$, $\Delta\lambda \fallingdotseq 1.1\times10^{-3}\mu m=1.1nm$. Accordingly, when the oscillation wavelength difference between $\lambda 1$ and $\lambda 2$ is 1nm or more, the correlation of the observed speckle patterns is reduced due to the respective semiconductor lasers, and consequently, the speckle patterns are averaged.

[0016]

From the aspect of averaging of the spatial speckle patterns, in order to efficiently perform the averaging, it is desired that the oscillation wavelength interval between arbitrary adjacent semiconductor lasers should be (A/2)nm or less, when the oscillation wavelengths of semiconductor lasers constituting the laser array vary within a range of Anm (A: real number). Further, when the laser array comprises N pieces of semiconductor lasers, the oscillation wavelengths preferably vary at intervals of approximately (A/N)nm. Further, from the above-described reasons, more effective speckle noise reduction can be realized when (A/N)>1nm. Further, although the output intensities of the respective semiconductor lasers are desired to be approximately uniform, it is confirmed that the speckle noise reduction effect can be sufficiently achieved if, using the semiconductor laser having the highest output intensity as a reference, the remaining semiconductor lasers have output intensities not less than 50% of the highest output intensity.

[0017]

Furthermore, the oscillation wavelength range A of the

semiconductor lasers is desirably 30nm or lower. The reason is as follows. When the high-power laser light source having a uniform cross-section light intensity according to the present invention is used as one for an image display unit, the effect of reducing the speckle noises and the effect of enhancing the color purities of red, blue, and green can be simultaneously obtained.

[0018]

As another example of the present invention, also when a cell having a hollow structure is used for the waveguide and a liquid comprising a transparent material and having a wavelength of the used semiconductor lasers is sealed in the cell, similar cross-section light intensity uniformization can be achieved. In this construction, the heat generated in the semiconductor lasers can be radiated to the waveguide by bonding the waveguide and the laser array in the state where the thermal resistance is small. Further, the heat radiation efficiency can be further enhanced by convecting the liquid in the cell. Furthermore, the heat-radiating and cooling effects of the laser array can be significantly improved by providing a cooling mechanism directly connected to the waveguide in addition to the waveguide of the hollow cell structure, and circulating the liquid filled in the hollow cell.

[0019]

(Embodiment 2)

The realization and effect of the high-power laser light

source having a uniform emission-light cross-section intensity distribution have been described in the first embodiment. In this second embodiment, a lighting optical system using the laser light source and a two-dimensional image formation device having the lighting optical system will be described.

[0020]

Figure 7 shows an example of a lighting optical system using a laser light source having an emission-light cross-section intensity distribution and a spatial light modulation device. In figure 7, 16 denotes a semiconductor laser, 17 denotes a waveguide, 18 denotes a lens, 19 denotes a liquid crystal panel as a spatial light modulation device, 20 denotes a laser light emitted from the waveguide 17, and 21 denotes the laser light that has transmitted through the liquid crystal panel 19. As described in the first embodiment, a laser light source having a uniform cross-section light intensity distribution is formed by the semiconductor laser 16 and the waveguide 17, and the cross-section light intensity distribution of laser light outputted from the semiconductor laser 16 to the waveguide 17 is uniformized while the light propagates in the waveguide 17, resulting in laser light 20. Further, an image at the emission end surface of the waveguide 17 (i.e., the laser light 20) is enlarged by the lens 18 and projected on the liquid crystal panel 19. At this time, for example, the shape of the cross-section of the waveguide 17 is made similar to the shape of the liquid

crystal panel 19, whereby the laser light 20 can be effectively applied to the liquid crystal panel 19 without losing most of the quantity of the laser light 20. The laser light 20 applied to the liquid crystal panel 19 is modulated into laser light 21 having an arbitrary intensity distribution (i.e., to be displayed as a two-dimensional image) by giving a two-dimensional image signal to the liquid crystal panel 19. Using such lighting optical system, displays of various sizes such as a rear projection type display and a head mount display can be realized. Further, it is also possible to project the laser light that has transmitted through the spatial light modulation device onto the screen by using an appropriate projection optical system. Figure 8 shows an example of a two-dimensional image formation device using a projection lens in addition to the structure of the lighting optical system described above. In figure 8, 22 denotes a lighting optical system including a laser light source having a uniform cross-section light intensity, and a spatial light modulation device, 23 denotes a projection lens, and 24 denotes laser light that has transmitted through the lighting optical system 22. As described above, in the lighting optical system 22, the laser light applied to the spatial light modulation device with the uniform light intensity distribution is modulated to laser light 24 having an arbitrary intensity distribution by the spatial light modulation device, and enlarged and projected onto the screen by the projection lens 23. Since a small-size and

high-power laser light source having a uniform cross-section light intensity can be easily achieved by using the laser light source of the present invention, a small-size laser projector capable of performing projection in 100-inch size class can be realized. Further, the construction that can reduce the speckle noise by controlling the oscillation wavelength of the semiconductor laser, which is one of the advantageous points of the present invention described in the first embodiment, is effective for space saving and cost reduction in the entire device due to a reduction in the number of optical members.

[0021]

While in this second embodiment the lighting optical system having a single waveguide is described, it is possible to realize a full-color two-dimensional image formation by setting the wavelengths of semiconductor lasers to those corresponding to red, blue, and green and providing laser light sources of the same construction for the respective colors. Further, application to a semiconductor exposure device or the like which requires high output power and uniform lighting is also possible by using semiconductor lasers in an ultraviolet wavelength band.

[Applicability in Industry]

[0022]

The present invention relates to a high-power laser light source having a uniform intensity distribution, and it is applicable to high-power lighting, laser assist processing, or

the like. Further, it is also applicable to an image display device such as a television receiver or a video projector, and an image formation device such as a semiconductor exposure device.

[Brief Description of the Drawings]

[0023]

Figure 1 is a diagram illustrating an example of a laser light source obtained by integrating a laser array comprising plural semiconductor lasers and a waveguide, according to the first embodiment of the present invention.

Figure 2 is a diagram schematically illustrating changes in light intensity distributions at arbitrary cross sections of the waveguide, of laser lights incident applied to the waveguide from the plural semiconductor lasers, according to the first embodiment of the present invention.

Figure 3 is a diagram illustrating an example of a laser light source obtained by integrating laser arrays arranged in a stack and a waveguide, according to the first embodiment of the present invention.

Figure 4 is a diagram geometric-optically illustrating a laser light propagating optical path in a waveguide in the case where a single semiconductor laser and a waveguide are used, according to the first embodiment of the present invention.

Figure 5(a) is a diagram illustrating an intensity distribution of laser light propagating in s free space in the case where a single semiconductor laser exists in the free space

(in the case where no waveguide exists) according to the first embodiment, figure 5(b) is a diagram illustrating reflections of the light intensity distribution at the side walls of the waveguide as well as the folded and overlapped light intensity distribution in the case where the single semiconductor laser and the waveguide are used according to the first embodiment of the present invention, and figure 5(c) is a diagram illustrating the light intensity distribution that is actually overlapped due to the reflections of the light intensity distribution at the side walls of the waveguide, in the case where the single semiconductor laser and the waveguide are used, according to the first embodiment of the present invention.

Figure 6(a) is a diagram geometric-optically illustrating a laser light propagating optical path in a waveguide of a laser light source obtained by integrating plural laser arrays and a waveguide, according to the first embodiment of the present invention, and figure 6(b) is a diagram geometric-optically illustrating a laser light propagating optical path in a waveguide of a laser light source obtained by integrating laser arrays arranged in a stack and a waveguide, according to the first embodiment of the present invention.

Figure 7 is a diagram illustrating an example of a lighting optical system including a laser light source having a uniformized cross-section light intensity distribution and a spatial light modulation device, according to the second

embodiment of the present invention.

Figure 8 is a diagram illustrating an example of a two-dimensional image formation device having a projection optical system in addition to the lighting optical system including a laser light source having a uniformized cross-section light intensity distribution and a spatial light modulation device, according to the second embodiment of the present invention.

[Description of Reference Numerals]

[0024]

1,5,8,12,14,16 ... semiconductor laser

2,6,9 ... laser array

3,7,10,13,15,17 ... waveguide

4,11 ... emitted light

18 ... lens

19 ... liquid crystal panel

20,21,24 ... laser light

22 ... lighting optical system

23 ... projection lens

[Name of the Document] Abstract

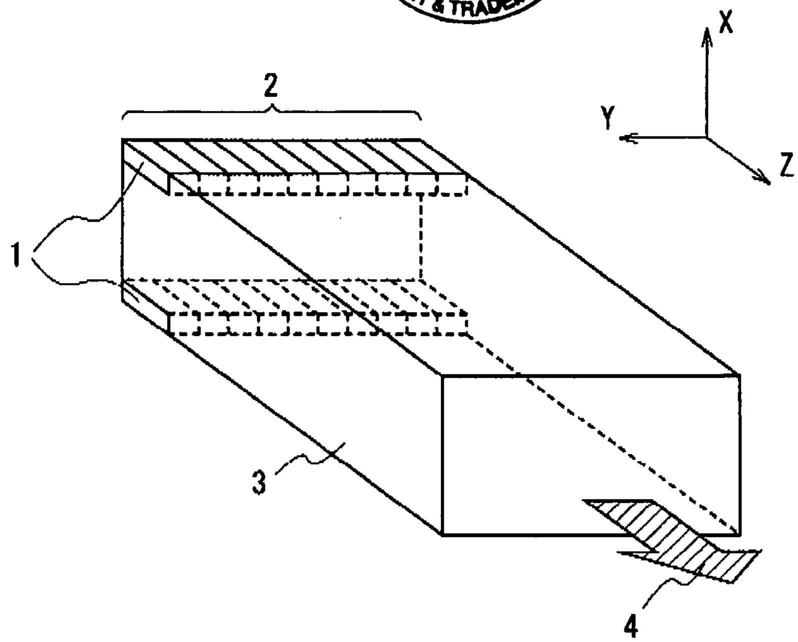
[Summary]

[Object] It is an object to provide a high-power light source, particularly, a high-power laser light source, having a uniform cross-section light intensity distribution.

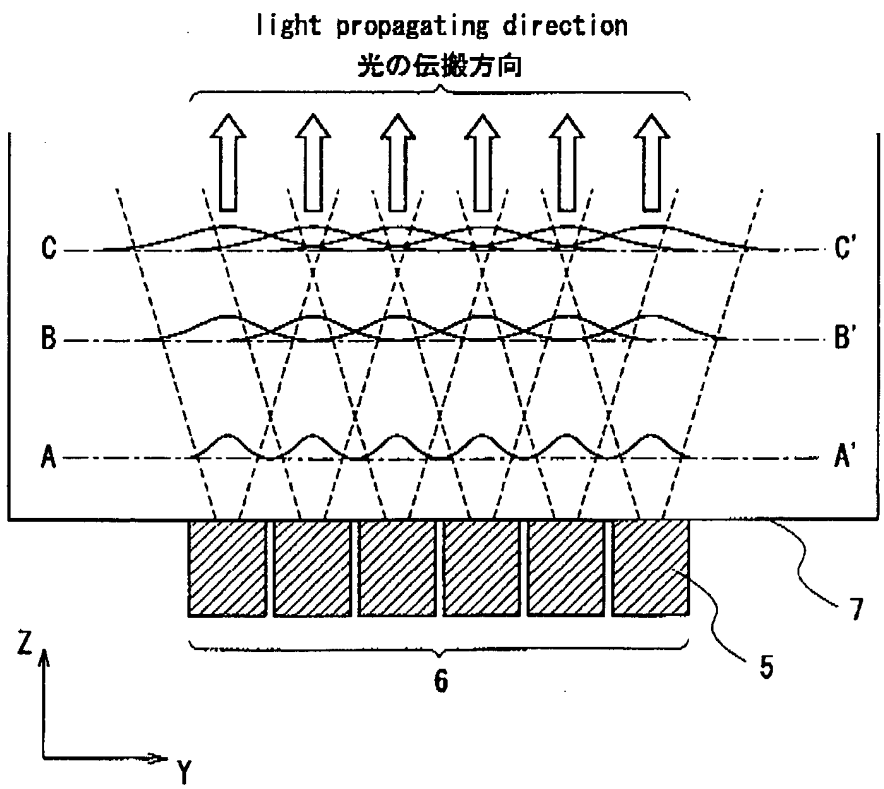
[Solution] There is provided a laser light source comprising plural semiconductor lasers and a waveguide, wherein the semiconductor lasers are disposed in the waveguide or in a position adjacent to the waveguide, and emitted lights from the semiconductor lasers are inputted to the waveguide from one end surface or a center of the waveguide, and outputted from an end surface of the waveguide different from the one end surface thereof. Further, there are provided a lighting optical system including the laser light source and a spatial light modulation means, and a two-dimensional image formation device.

[Selected Figure] Fig.1

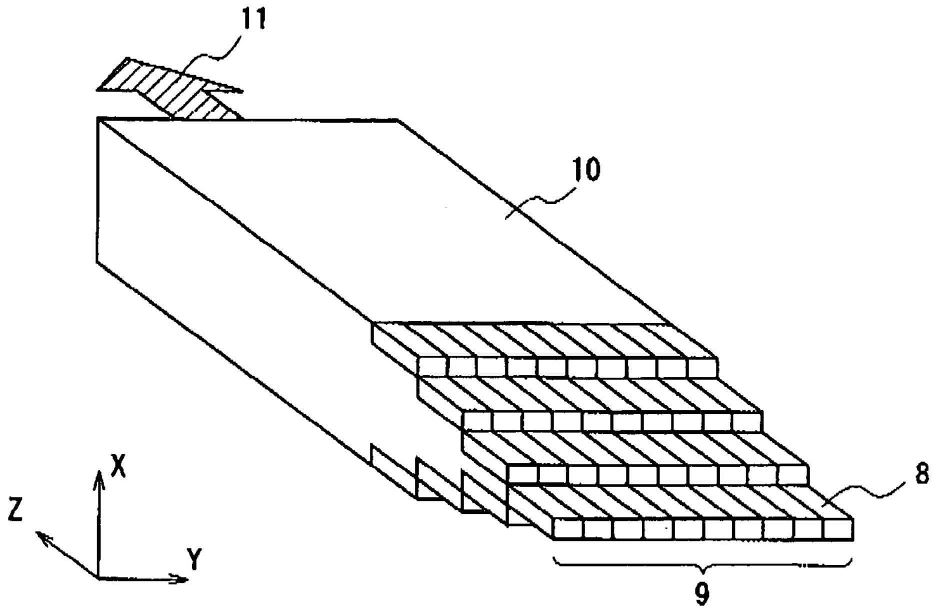
Name of Document
【書類名】 図面 Drawing
【図1】 Figure 1



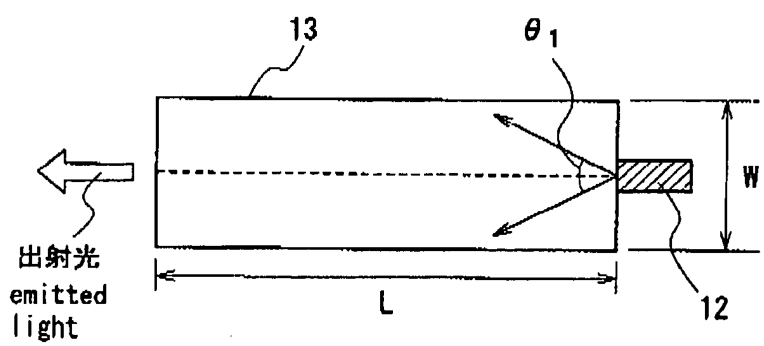
【図2】 Figure 2



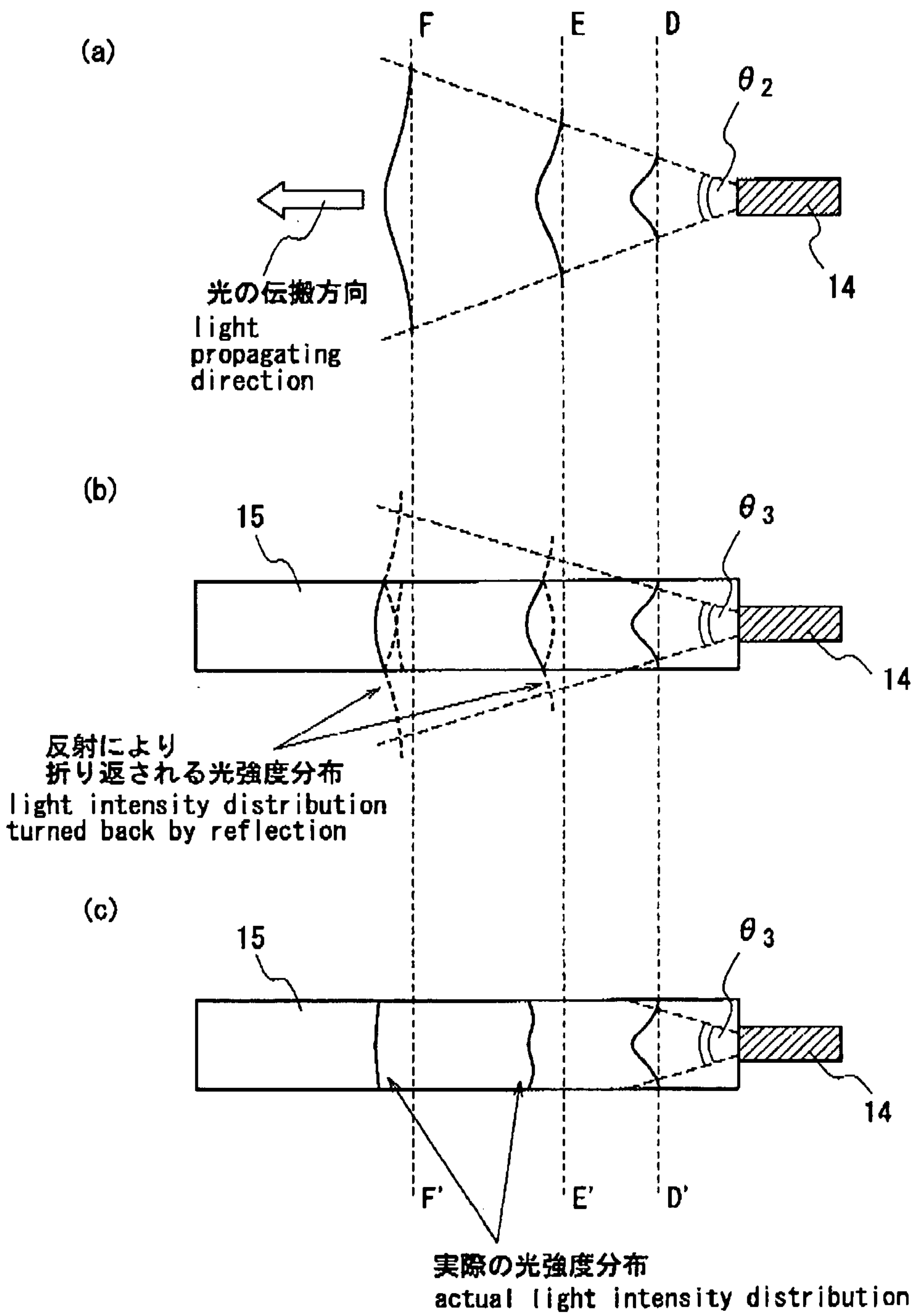
【図3】 Figure 3



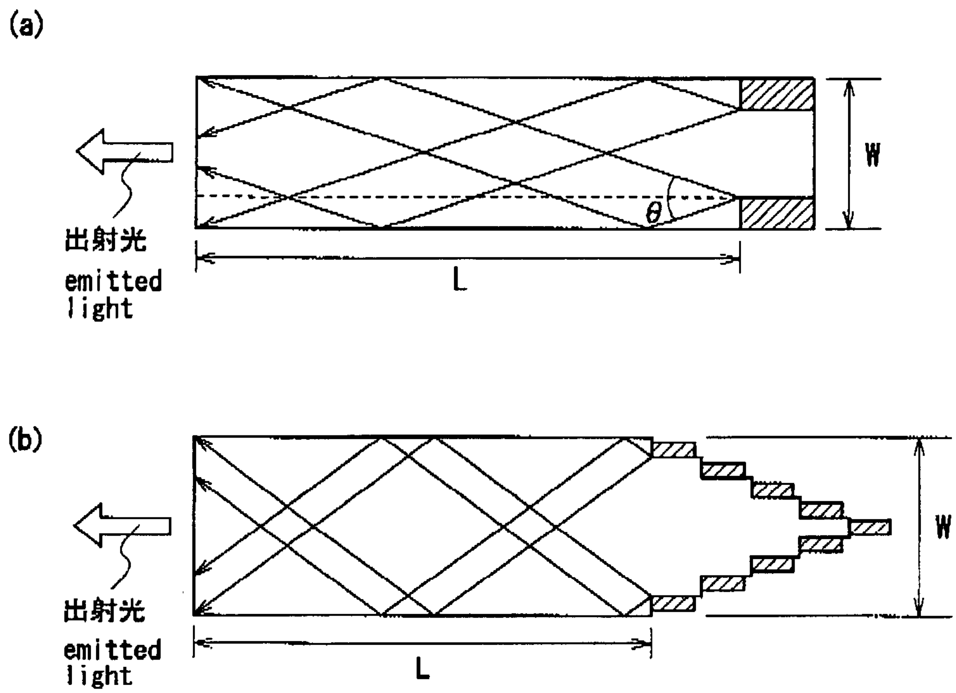
【図4】 Figure 4



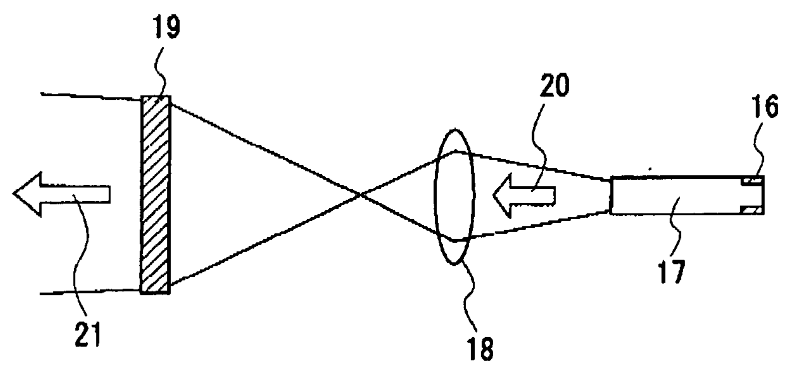
【図5】　Figure 5


(a)
F
E
D
θ2
14
光の伝搬方向
light
propagating
direction
(b)
15
θ3
14
反射により
折り返される光強度分布
light intensity distribution
turned back by reflection
(c)
15
θ3
14
F'
E'
D'
実際の光強度分布
actual light intensity distribution

【図6】　Figure 6



【図7】　Figure 7



【図8】 Figure 8